Claims

We claim:

1. An apparatus for controlling a fluid flow rate of at least one pump and an air flow rate of at least one fan, in a cooling system for cooling at least one device, the apparatus comprising:
at least one temperature sensor coupled to measure a temperature value of the at least one device; and
a controller coupled to receive the temperature value from the at least one temperature sensor and to selectively control the fluid flow rate and the air flow rate, based on the temperature value.

2. The apparatus of claim 1, wherein the fluid flows in a closed loop.

3. The apparatus of claim 1, wherein the device comprises an electronic circuit.

4. The apparatus of claim 3, wherein the electronic circuit is a microprocessor.

5. The apparatus of claim 1, further including a heat exchanger thermally coupled to the device where at least a portion of the heat exchanger is filled with a thermal capacitance medium for maintaining the temperature value of the device below a maximum allowable temperature during thermal transients.

6. The apparatus of claim 5, wherein the medium is laterally distributed in the heat exchanger.

7. The apparatus of claim 5, wherein the at least one pump and the at the least one fan are controlled such that the temperature value of the device is maintained below a maximum allowable temperature.

8. The apparatus of claim 5, wherein the at least one fan is maintained at a constant maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustics transients are reduced.

9. The apparatus of claim 5, wherein the at least one fan is ramped up to a maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced.

10. The apparatus of claim 5, wherein the at least one fan is ramped down to a minimum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced.

11. The apparatus of claim 1, further including at least one current sensor coupled to the at least one device, to provide information which is representative of current delivered to the at least one device and indicative of total power consumed by the at least one device, wherein the controller is coupled to receive the information provided by the at least one current sensor.

12. The apparatus of claim 1, further including at least one sensor measuring a pressure of the fluid at any position in the system, wherein the controller is coupled to receive the information provided by the at least one sensor.

13. The apparatus of claim 1, wherein the at least one temperature sensor measures

temperature values of ambient air around the device.

14. The apparatus of claim 1, wherein the at least one temperature sensor measures temperature values of the fluid at any point in the cooling system.

15. The apparatus of claim 1, wherein the controller adjusts a current supplied to the at least one pump in response to the measured temperature value of the device.

16. The apparatus of claim 1, wherein the controller adjusts a voltage supplied to the at least one pump in response to the measured temperature value of the device.

17. The apparatus of claim 1, wherein the controller adjusts a current supplied to the at least one fan in response to the measured temperature value of the device.

18. The apparatus of claim 1, wherein the controller adjusts a voltage supplied to the at least one fan in response to the measured temperature value of the device.

19. The apparatus of claim 1, wherein the controller adjusts an average power supplied to the at least one fan with a pulse width modulated signal.

20. The apparatus of claim 1, further including a valve for regulating the fluid flow rate, which is selectively opened and closed to a variable state in response to the measured temperature value.

21. The apparatus of claim 1, wherein the at least one pump is controlled independently of the at least one fan.

22. The apparatus of claim 1, wherein the at least one pump is controlled cooperatively with the at least one fan.

23. The apparatus of claim 1, wherein a power consumption of the cooling system is reduced to a minimal level by changing a power delivered to the at least one pump and the at least one fan.

24. The apparatus of claim 1, wherein a noise of the at least one pump is held constant while the at least one fan is used to control the temperature value of the device.

25. The apparatus of claim 1, wherein a noise of the at least one fan is held constant while the at least one pump is used to control the temperature value of the device.

26. The apparatus of claim 1, wherein time variations in noise level of the at least one fan is minimized according to predetermined criteria.

27. The apparatus of claim 1, wherein time variations in noise level of the at least one pump is minimized according to predetermined criteria.

28. The apparatus of claim 1, wherein time variations in noise level of the at least one pump and the at least one fan is minimized according to predetermined criteria.

29. The apparatus of claim 1, wherein a sum of the noise level of the at least one fan and the at least one pump is minimized.

30. The apparatus of claim 1, wherein the temperature values of the at least one device are maintained between a minimum temperature level and a maximum temperature level, such that

the power consumption of the cooling system is reduced to a minimum level.

31. The apparatus of claim 1, wherein the controller includes a control algorithm based on a thermal time constant, wherein the thermal time constant is a product of a thermal resistance value and a thermal capacitance value.

32. The apparatus of claim 31, wherein the thermal time constant is being applied to develop optimal control schemes for at least one of the at least one pump and the at least one fan, in response to power consumed from the at least one device.

33. The apparatus of claim 32, wherein the optimal control schemes include increase of fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.

34. The apparatus of claim 32, wherein the optimal control schemes include increase of fluid flow rate of the at least one pump, with a gradual increase of air flow rate of the at least fan, so that acoustic noise variations are maintained below a predetermined limit.

35. The apparatus of claim 32, wherein the optimal control schemes include gradual decrease of air flow rate of the at least one fan so acoustic noise variations are maintained below a predetermined limit.

36. The apparatus of claim 32, wherein the optimal control schemes include decrease of fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.

37. A method of controlling a fluid flow rate of at least one pump and an air flow rate of at least one fan, in a cooling system for at least one device, the method comprising the steps of:

providing at least one temperature sensor coupled to measure a temperature value of the at least one device;

receiving the temperature value from the at least one temperature sensor; and

providing a controller to selectively control at least one of the fluid flow rate and the air flow rate, based on the at least one temperature value.

38. The method of claim 37, wherein the fluid flows in a closed loop.

39. The method of claim 37, wherein the device comprises an electronic circuit.

40. The method of claim 39, wherein the electronic circuit is a microprocessor.

41. The method of claim 37, further including the step of filling at least a portion of a heat exchanger with a high thermal capacitance medium for maintaining the temperature value of the device below a maximum allowable temperature, wherein the heat exchanger is thermally coupled to the device.

42. The method of claim 41, wherein the medium is laterally distributed in the heat exchanger.

43. The method of claim 41, wherein the at least one pump and the at least one fan are controlled such that the temperature value of the device is maintained below a maximum allowable temperature.

44. The method of claim 41, wherein the at least one fan is maintained at a constant maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustics transients are

reduced below a given limit.

45. The method of claim 41, wherein the at least one fan is ramped up to a maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced below a given limit.

46. The method of claim 41, wherein the at least one fan is ramped down to a minimum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced below a given limit.

47. The method of claim 37, further including the step of providing at least one current sensor coupled to the at least one device, to provide information which is representative of current delivered to the at least one device and indicative of power consumed by the at least one device, wherein the controller is coupled to receive the information provided by the at least one current sensor.

48. The method of claim 37, further including the step of providing at least one sensor measuring a pressure of the fluid at any position in the system, wherein the controller is coupled to receive the information provided by the at least one sensor.

49. The method of claim 37, wherein the at least one temperature sensor measures temperature values of ambient air around the device.

50. The method of claim 37, wherein the at least one temperature sensor measures temperature values of the fluid at any point in the cooling system.

51. The method of claim 37, wherein the controller adjusts a current supplied to the at least one pump in response to the measured temperature value of the device.

52. The method of claim 37, wherein the controller adjusts a voltage supplied to the at least one pump in response to the measured temperature value of the device.

53. The method of claim 37, wherein the controller adjusts a current supplied to the at least one fan in response to the measured temperature value of the device.

54. The method of claim 37, wherein the controller adjusts a voltage supplied to the at least one fan in response to the measured temperature value of the device.

55. The method of claim 37, wherein the controller adjusts an average power supplied to the at least one fan with a pulse width modulated signal.

56. The method of claim 37, further including a valve for regulating the fluid flow rate, which is selectively opened and closed to a variable state in response to the measured temperature value.

57. The method of claim 37, wherein the at least one pump is controlled independently of the at least one fan.

58. The method of claim 37, wherein the at least one pump is controlled cooperatively with the at least one fan.

59. The method of claim 37, wherein a power consumption of the cooling system is reduced to a minimal level by changing a power to the at least one pump and the at least one fan.

60. The method of claim 37, wherein a noise of the at least one pump is held constant while the at least one fan is used to control the temperature value of the device.

61. The method of claim 37, wherein a noise of the at least one fan is held constant while the at least one pump is used to control the temperature value of the device.

62. The method of claim 37, wherein time variations in noise level of the at least one fan are minimized according to a predetermined criteria.

63. The method of claim 37, wherein time variations in noise level of the at least one pump is minimized according to a predetermined criteria.

64. The method of claim 37, wherein time variations in noise level of the at least one pump and the at least one fan are minimized according to a predetermined criteria.

65. The method of claim 37, wherein a sum of the noise level of the at least one fan and the at least one pump is minimized.

66. The method of claim 37, wherein the temperature values of the at least one device are maintained between a minimum temperature level and a maximum temperature level, such that the power consumption of the cooling system is reduced to a minimum level.

67. The method of claim 37, wherein the controller includes a control algorithm based on a thermal time constant, wherein the thermal time constant is a product of a thermal resistance value and a thermal capacitance value.

68. The method of claim 67, wherein the thermal time constant is being applied to develop optimal control schemes for at least one of the at least one pump and the at least one fan, in response to power consumed from the at least one device.

69. The method of claim 68, wherein the optimal control schemes include increasing a fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.

70. The method of claim 68, wherein the optimal control schemes include increasing a fluid flow rate of the at least one pump, with a gradual increase of air flow rate of the at least fan, so that acoustic noise variations are maintained below a predetermined limit.

71. The method of claim 68, wherein the optimal control schemes include gradual decreasing an air flow rate of the at least one fan so acoustic noise variations are maintained below a predetermined limit.

72. The method of claim 68, wherein the optimal control schemes include decreasing a fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.

73. An apparatus for controlling a fluid flow rate of at least one pump and an air flow rate of at least one fan, in a cooling system for cooling at least one device, the apparatus comprising:

at least one circuit for measuring a current consumed by the device and for forming a signal representative thereof; and

a controller coupled to receive the signal and to selectively control the fluid flow rate and the air flow rate, in response thereto.

74. The apparatus of claim 73, wherein the fluid flows in a closed loop.

75. The apparatus of claim 73, wherein the device comprises an electronic circuit.

76. The apparatus of claim 75, wherein the electronic circuit is a microprocessor.

77. The apparatus of claim 73, further including a heat exchanger thermally coupled to the device where at least a portion of the heat exchanger is filled with a high thermal capacitance medium for maintaining a temperature value of the device below a maximum allowable temperature.

78. The apparatus of claim 77 wherein the medium is laterally distributed in the heat exchanger.

79. The apparatus of claim 77, wherein the at least one pump and the at the least one fan are controlled such that the temperature value of the device is maintained below a maximum allowable temperature.

80. The apparatus of claim 77, wherein the at least one fan is maintained at a constant maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustics transients are reduced below a given limit.

81. The apparatus of claim 77, wherein the at least one fan is ramped up to a maximum speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced below a given limit.

82. The apparatus of claim 77, wherein the at least one fan is ramped down to a minimum

speed and the at least one pump is controlled such that the temperature value of the device is maintained below a maximum allowable temperature and acoustic transients are reduced below a given limit.

83. The apparatus of claim 73, further including at least one sensor measuring a pressure of the fluid, wherein the controller is coupled to receive the information provided by the at least one sensor.

84. The apparatus of claim 73, further comprising at least one temperature sensor to measure temperature values of ambient air around the device.

85. The apparatus of claim 73, wherein the at least one temperature sensor measures temperature values of the fluid at any point in the cooling system.

86. The apparatus of claim 73, wherein the controller adjusts a current supplied to the at least one pump in response to the signal.

87. The apparatus of claim 73, wherein the controller adjusts a voltage supplied to the at least one pump in response to the signal.

88. The apparatus of claim 73, wherein the controller adjusts a current supplied to the at least one fan in response to the signal.

89. The apparatus of claim 73, wherein the controller adjusts a voltage supplied to the at least one fan in response to the signal.

90. The apparatus of claim 73, wherein the controller adjusts an average power supplied to the at least one fan with a pulse width modulated signal.

91. The apparatus of claim 73, further including a valve for regulating the fluid flow rate, which is selectively opened and closed to a variable state in response to the signal.

92. The apparatus of claim 73, wherein the at least one pump is controlled independently of the at least one fan.

93. The apparatus of claim 73, wherein the at least one pump is controlled cooperatively with the at least one fan.

94. The apparatus of claim 73, wherein a power consumption of the cooling system is reduced to a minimal level by changing a power delivered to the at least one pump and the at least one fan.

95. The apparatus of claim 73, wherein a noise of the at least one pump is held constant while the at least one fan is used to control the temperature value of the device.

96. The apparatus of claim 73, wherein a noise of the at least one fan is held constant while the at least one pump is used to control the temperature value of the device.

97. The apparatus of claim 73, wherein time variations in noise level of the at least one fan is minimized according to a predetermined criteria.

98. The apparatus of claim 73, wherein time variations in noise level of the at least one pump is minimized according to a predetermined criteria.

99. The apparatus of claim 73, wherein time variations in noise level of the at least one pump

and the at least one fan is minimized according to a predetermined criteria.

100. The apparatus of claim 73, wherein a sum of the noise level of the at least one fan and the at least one pump is minimized.

101. The apparatus of claim 73, wherein the temperature values of the at least one device are maintained between a minimum temperature level and a maximum temperature level, such that the power consumption of the cooling system is reduced to a minimum level.

102. The apparatus of claim 73, wherein the controller includes a control algorithm based on a thermal time constant, wherein the thermal time constant is a product of a thermal resistance value and a thermal capacitance value.

103. The apparatus of claim 102, wherein the thermal time constant is being applied to develop optimal control schemes for at least one of the at least one pump and the at least one fan, in response to power consumed from the at least one device.

104. The apparatus of claim 103, wherein the optimal control schemes include increase of fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.

105. The apparatus of claim 103, wherein the optimal control schemes include increase of fluid flow rate of the at least one pump, with a gradual increase of air flow rate of the at least fan, so that acoustic noise variations are maintained below a predetermined limit.

106. The apparatus of claim 103, wherein the optimal control schemes include gradual decrease of air flow rate of the at least one fan so acoustic noise variations are maintained below a predetermined limit.

107. The apparatus of claim 103, wherein the optimal control schemes include decrease of fluid flow rate of the at least one pump, with no increase of air flow rate of the at least one fan.